MCMAD: A Narrow-Band Microwave Amplifier Design Program

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Abstract

MCMAD, a program for the design of narrow-band microwave amplifiers has been developed. Starting from the measured scattering parameters, or the manufacturer's given parameters of the device, MCMAD optimizes the amplifier to meet one of the following requirements: maximum gain, minimum noise figure, or maximum gain restricted by a user-given maximum allowable value of noise figure. It implements the input and output matching networks using microstrip transmission lines. The program also ensures that the proposed amplifier is stable in the entire frequency band. This avoids any instabilities that might occur outside the desired narrow-band, due to any external noise. For transistors having stability factor, K, less than unity, the design of maximum gain amplifiers using MCMAD, has much larger gain than the stable gain typically assumed.

For this case, $K < 1$, the transistor is potentially unstable, the design technique which is widely used is based on the assumption that the maximum stable gain of the amplifier is equal to $|\frac{S_{21}}{S_{12}}|$. Practically, the designer is limited to an even smaller value of gain[1,3]. This result was reached by equating the radius of constant operating power gain circles, R_P[1,2,3], to zero, as in the case $K > 1$, and taking the limiting case corresponding to $K = 1$. This procedure is not valid as R_P can never take the value zero for any value of $K < 1$. Therefore, the amplifier can have larger gain than $|\frac{S_{21}}{S_{12}}|$ and still be stable as will be shown later in the design example.

Design Approach

The MCMAD design methodology of narrow-band microwave amplifiers is first to choose the optimum source impedance that provides maximum stable available power gain G_A. This optimum value depends on whether the amplifier is designed to be a maximum gain, a maximum gain restricted by a user-given value of noise figure, or a low noise amplifier. It also depends on whether the transistor is conditionally stable, or potentially unstable[4].

The second step of the design methodology is to choose the optimum load impedance that achieves maximum transducer power gain. This optimum load impedance also depends on the stability circumstances of the transistor[4]. The third design step is to test the stability of the designed amplifier in the entire frequency band. The amplifier is stable in the entire frequency band, if both the magnitude of the input reflection coefficient, and the magnitude of the output reflection coefficient are less than unity for any frequency point that has amplifier gain greater than unity (+ve dB). The Final design step is to implement the resulting output and input matching circuit using microstrip lines[2].

Design Example

Using the Fujitsu fsc10 transistor whose scattering parameters are shown in Figure 1, MCMAD has been used to design a maximum gain amplifier at 3GHz. From the transistor scattering parameters, it can be shown that this transistor is potentially unstable ($K < 1$) for frequencies below 4.8GHz.

As shown in Figure 2, the designed amplifier using MCMAD is stable in the entire frequency band, and has a stable gain of 126 (21dB) at 3GHz, however, the stable gain typically assumed is less than $|\frac{S_{21}}{S_{12}}|$, i.e., less than 63.

freq.	S_{11}		S_{21}		S_{12}		S_{22}	
GHz	Mag.	Phase	Mag.	Phase	Mag.	Phase	Mag.	Phase
2	0.915	-49	3.766	128	0.040	56	0.510	-40
3	0.869	-63	3.285	114	0.052	46	0.503	-48
4	0.784	-80	2.982	100	0.056	40	0.497	-58
5	0.725	-91	2.821	87	0.064	33	0.490	-69
6	0.667	-103	2.701	73	0.069	27	0.477	-79
7	0.608	-118	2.661	59	0.075	21	0.471	-88
8	0.516	-140	2.592	42	0.082	11	0.405	-104
9	0.464	-174	2.496	21	0.083	-2	0.353	-126
10	0.464	161	2.384	5	0.084	-12	0.353	-143
11	0.484	137	2.163	-12	0.088	-20	0.346	-165
12	0.529	118	1.790	-31	0.083	-40	0.359	156

Figure 1: fsc10 S-parameters from Fujitsu's data sheet.

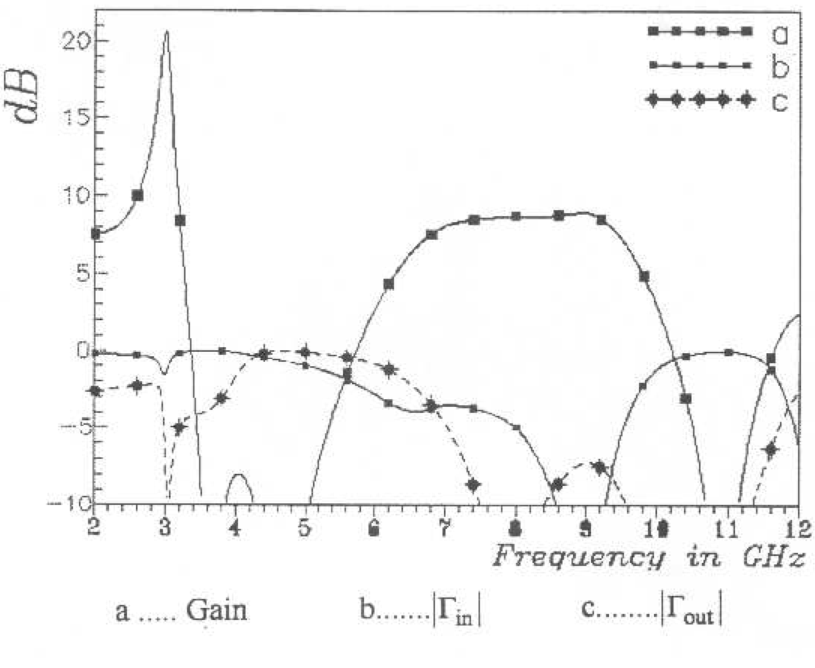

Figure 2: Stable gain performance of the designed amplifier.

References

[1] G. D. Vendelin, Design of Amplifiers and Oscillators by the S-Parameter Method, John Wiley & Sons, Inc., 1982.

[2] G. Gonzlez, Microwave Transistor Amplifiers Analysis and Design, Prentice Hall, Inc., 1984.

[3] S. Y. Liao, Microwave Circuits Analysis and Design, Prentice Hall, Inc., 1987, pp.112-113.

[4] Y. Massoud, "Computer Aided Design of Low-Noise and Broad-Band Microwave Transistor Amplifiers", Masters Thesis, Cairo University, June 1994.